Fermi National Accelerator Laboratory

FERMILAB-Conf-96/389-E

DØ

New Phenomena Results Presented at the 1996 A.P.S. Division of Particles and Fields Meeting

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October 1996

Submitted to the *1996 Annual Divisional Meeting (DPF 96) of the Division of Particles and Fields of the American Physical Society*, Minneapolis, Minnesota, August 10-15, 1996.

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FERMILAB Conf-96/389-E

DØ New Phenomena Results Presented at the 1996 A.P.S. Divison of Particles and Fields Meeting

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Abstract

This paper is a compendium of the DØ papers submitted to the 1996 Divison of Particles and Fields meeting in Minneapolis/St. Paul, Minnesota. Each paper is reproduced here in full.

Contents

A Search for Squarks and Gluinos in the Dielectron Channel Within a Consistent Supergravity Framework at DØ

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A search for squarks and gluinos has been performed with the DØ detector using the ee + two jets + missing transverse energy signature. Data corresponding to 92.9 pb^{-1} were analyzed from the 1994-1995 run of the Fermilab Tevatron Collider. No excess over Standard Models backgrounds is observed. This result is interpreted using a consistent supergravity framework to derive limits in the m_0–$m_{1/2}$ plane.

1 SUSY and SUGRA

Supersymmetry (SUSY) is a space–time symmetry giving every Standard Model (SM) fermion a super–particle partner (***sparticle***) boson and every SM boson a sparticle fermion. The analysis described here is a search for squarks and gluinos. We assume R–parity conservation and that the LSP is the lightest neutralino, $\tilde{\chi}_1^0$.

Supergravity[1] (SUGRA) is a SUSY model that includes gravity at the Planck scale. At that energy scale, the gauginos are mass degenerate (true for any grand unified theory) as are the SUSY scalars in the simple SUGRA model employed here. SUGRA requires specifying only, (1) m_0, the common scalar mass; (2) $m_{1/2}$, the common gaugino mass; (3) A_0, the trilinear coupling constant; (4) $\tan\beta$, the ratio of the Higgs doublets VEVs; and (5) the sign of μ, the Higgsino mixing parameter. The magnitude of μ is constrained to produce the correct Z mass through electroweak symmetry breaking. Once these parameters are fixed, the masses and mixings of the SUSY particles at the weak scale are determined by running of the renormalization group equations. With these few parameters, SUGRA allows exploration of a substantial portion of parameter space and enables searches for different SUSY particles to be combined in a consistent manner.

2 The dielectron search

A squark or gluino decays through a cascade of charginos and neutralinos to a final state of one or more quarks, possible leptons and an LSP. Searches for states with a lepton suffer from low branching fractions, but backgrounds are small. With sufficient efficiency, a search for leptonic final states is possible and has been performed at DØ as described here. The signature is events with two electrons, at least two jets and missing transverse energy.

Data corresponding to a total integrated luminosity of 92.9 pb^{-1} from the 1994-1995 Tevatron run were collected by a trigger requiring one cluster in the electromagnetic calorimeter with $E_T > 15$ GeV, another EM cluster with $E_T > 10$ GeV and $\not{E}_T > 14$ GeV. Nearly 120,000 events satisfied the trigger. Offline cuts were, (1) two electrons with $E_T > 15$ GeV and $|\eta| < 2.5$ (rejects heavy flavor background); (2) $|m_{ee} - m_{Z^0}| > 12$ GeV if $\not{E}_T < 40$ GeV (eliminates $Z \rightarrow ee$ background); (3) $\not{E}_T > 25$ GeV (rejects $Z \rightarrow \tau\tau \rightarrow ee$ background); and (4) 2 jets with $E_T > 20$ GeV within $|\eta| < 2.5$ (rejects $WW \rightarrow ee$). Two events pass these requirements with 3.0 ± 1.3 events expected from backgrounds. The largest background expected is 1.2 ± 0.4 events from top production. One of the two passing data events is a top dilepton candidate. The other fails a top dilepton analysis requirement on the sum of jet and electron energies. No excess of events over expected backgrounds was observed.

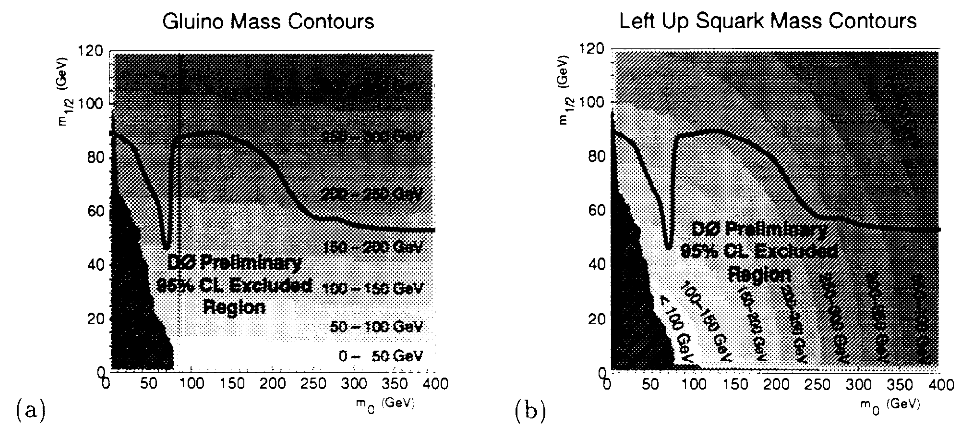

Figure 1: (a) The 95% CL limit in the $m_0 - m_{1/2}$ plane shown overlayed with contours of constant gluino mass. (b) The identical limit, shown with contours of constant squark mass.

To interpret the lack of excess, production of SUSY particles were simulated using ISAJET[2] within the consistent SUGRA framework. Production of squarks and gluinos dominated the acceptance. The fixed SUGRA parameters were $\tan\beta = 2$, $A_0 = 0$, and $\mu < 0$ along with $m_{top} = 180$ GeV. We varied m_0 and $m_{1/2}$. From kinematic efficiencies determined by ISAJET and electron ID efficiencies determined from data, the total efficiency was calculated at many points in the $m_0 - m_{1/2}$ plane. A 95% CL cross section limit was determined at each $(m_0, m_{1/2})$ point with a Bayesian limit calculation using a flat prior probability for the signal cross sections and systematic errors represented by Gaussians. Using ISAJET leading order cross sections, the mass limit shown in Fig. 1 in the $m_0 - m_{1/2}$ plane was constructed. The solid black line (identical in both plots) is the 95% CL exclusion contour. The hashed region indicates where the SUGRA model is invalid (no EWSB, $\tilde{\chi}_1^0$ not the LSP, etc.). The exclusion contour is overlayed on contours of constant gluino or squark mass.

For $m_0 >\sim 90$ GeV, the $\tilde{\chi}_2^0$ can decay to electrons and gives a large contribution to the final state branching fraction. At $m_0 \sim 90$ GeV, the $\tilde{\nu}_\ell$ becomes lighter than the $\tilde{\chi}_2^0$ and thus the $\tilde{\chi}_2^0$ decays totally to invisible particles, eliminating its contribution to the ee signature. This abrupt change in the BF is seen as the large dip in the exclusion contour. As m_0 decreases, $\tilde{e}_\ell$ eventually becomes lighter than the $\tilde{\chi}_2^0$, and so the $\tilde{\chi}_2^0$ can decay into electrons through the selectron, thus restoring the signature. So called "supergravity" searches that fix sneutrino masses miss this important feature.

The effects of changing the SUGRA parameters is being studied. At the Tevatron energy, changes in A_0 have little effect. If $\mu > 0$ then the mass difference between $\tilde{\chi}_2^0$ and $\tilde{\chi}_1^0$ becomes small, and the leptons produced are very soft making limit setting difficult. When $\tan\beta$ is changed the Higgs sector is altered, thus changing SUSY particle masses and the Higgs content of the gauginos. As $\tan\beta$ is raised, the total efficiency appears to drop, but the production cross section increases.

3 Summary

We have searched for squarks and gluinos decaying to ee + $\geq$2 jets + $\not{E}_T$. No excess over SM backgrounds is observed in 92.9 pb^{-1} of data. This result, for the first time, is interpreted in a consistent supergravity model. An exclusion contour in the $m_0 - m_{1/2}$ plane is constructed.

References

1. S. Deser and B. Zumino, ***Phys. Lett.*** B **62**, 335 (1976); P. van Nieuwenhuizen, ***Phys. Rep.*** **68**, 189 (1981); S. Ferrara, R. Barbieri and C. Savoy, ***Phys. Lett.*** B **119**, 343 (1982).
2. F. Paige and S. Protopopescu, in ***Supercollider Physics***, p. 41, ed. D. Soper (World Scientific); H. Baer ***et. al.***, in ***Proceedings of the Workshop on Physics at Current Accelerators and Supercolliders***, ed. J. Hewett, A. White and D. Zeppenfeld (Argonne Natl. Laboratory, 1993).

Search For Excited Quarks Decaying to Two–Jets with the DØ Detector

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We present preliminary results from a search for new particles decaying to dijets using data collected during the 1994 to 1995 collider run with an integrated luminosity of 91 pb^{-1}. Confidence limits on the production cross sections of excited quarks are presented.

There are many extensions to the Standard Model that predict the existence of new massive objects (e.g. excited quarks, W', Z', etc.[1,2]) which couple to quarks and gluons and will form resonant structures in the dijet mass spectrum. We report on a search for excited quarks decaying to two–jets.

The data sample was collected during the 1994–95 data taking period and corresponds to a luminosity of 91 pb^{-1}. A complete description of the data selection can be found in Reference 3. For each event the dijet mass can be calculated (assuming massless jets): $M_{jj}^2 = 2 \cdot E_{T1} \cdot E_{T2} \cdot (\cosh(\Delta\eta) - \cos(\Delta\phi))$, where E_{T1} and E_{T2} are the transverse energies of the two leading E_T jets. Each event is weighted by the efficiency of the quality cuts applied to the data. Cuts are made on the pseudorapidity of the two leading E_T jets such that $|\eta_{1,2}| < 1.0$ and $\Delta\eta = |\eta_1 - \eta_2| < 1.6$ to increase the signal to background ratio. The data was collected using four triggers with E_T thresholds of 30, 50, 85 and 115 GeV with integrated luminosities of 0.36, 4.6, 52 and 91 pb^{-1}. These trigger samples were used to measure the dijet mass spectrum above mass thresholds of 200, 270, 370 and 500 GeV where each of the triggers is fully efficient.

The size of a possible signal, N_X, is extracted by fitting the measured dijet mass spectrum with a continuum distribution, Q_i, generated using JETRAD [4] which is smeared by the measured jet resolutions [3], plus a PYTHIA [6] generated excited quark line shape, S_i representing the signal (See Fig. 2): $F_i = A \times Q_i + N_X \times S_i$ where F_i is the fitted number of events per bin and A is the JETRAD normalization. The data have been binned so that there are at least five events per bin and fitted using a binned maximum likeliehood method. The cross section is then given by $\sigma_X \times \text{BR} \times a = N_X/\mathcal{L}$ where BR is the branching ratio to two–jets, a is the acceptance and $\mathcal{L}$ is the integrated luminosity. The resulting fit is plotted in Figs. 3 and 4. The fit shows that JETRAD is a good representation of the dijet mass spectrum. The data was fitted to determine N_X for excited quark line shapes. The uncertainty on the cross section is given by the sum in quadrature of the measurement error ΔN_X, the luminosity error (8%) and the data selection cuts (2%). The uncertainty in the mass scale is approximately 5% and is incorporated by plotting the CL at the mass which produces the most conservative limit. The 95% Confidence Limit is plotted and compared to the expected excited quark production cross sections times the branching ratio and acceptance (Fig. 5). The 95% CL rules out the existence of excited quarks with $M_{q^*} < 720$ GeV.

In conclusion we see no evidence for new particle production and set preliminary 95% confidence limits on excited quark production.

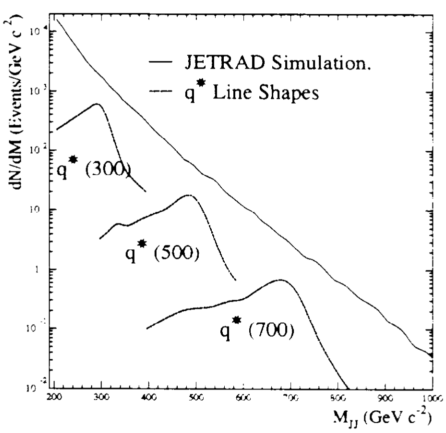

Figure 2: The JETRAD simulation of the QCD dijet mass spectrum with predicted excited quark line shapes.

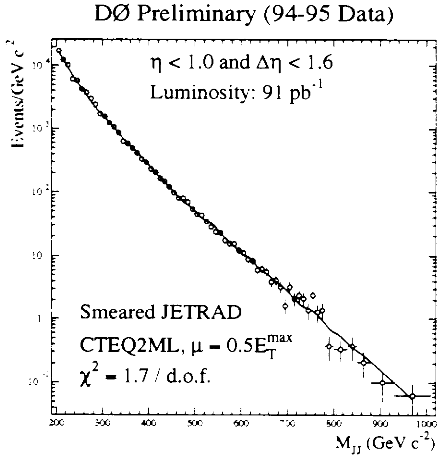

Figure 3: Fit to the dijet mass spectrum with the smeared JETRAD NLO calculation.

References

1. U. Baur, M. Spira and P.M. Zerwas, Phys. Rev. **D42**, 815 (1990)
2. J. Bagger, C. Schmidt and S. King, Phys. Rev. **D42**, 815 (1990)
3. S. Abachi *et al.* (DØ Collaboration), FERMILAB-CONF-96/168-E

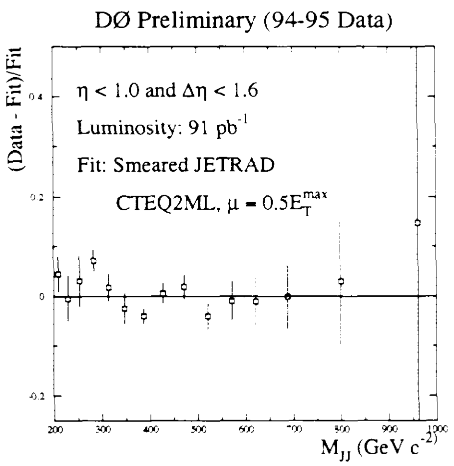

Figure 4: The difference, (Data-Fit)/Fit, between the data and the fit.

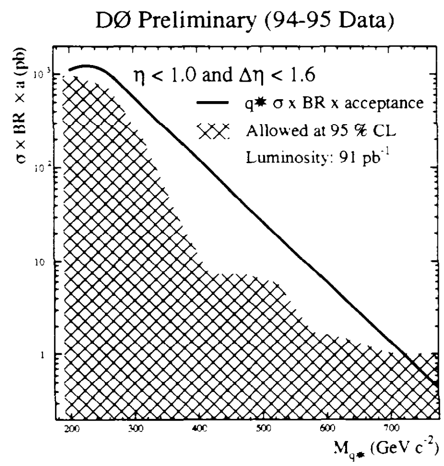

Figure 5: The calculated Cross Section and 95% Confidence Limits for excited quarks.

4. W.T. Giele, E.W.N. Glover and D.A. Kosower,Phys. Rev. Lett. **73**, 2019 (1994)
5. H.U. Bengtsson and T. Sjöstrand, Comp. Phys. Commun. **46** (1987) 43.
6. J. Botts, *et al.* (CTEQ Collaboration), Phys. Lett. **B304**, 159 (1993)

Search for Di-jet Resonances Produced in Association with W Bosons at DØ

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We report results from the DØ experiment of a search for events of the type $p\bar{p} \to WX$, where X is a particle which decays to $b\bar{b}$. We express our results as limits on the cross section for associated production of the standard model Higgs Boson.

4 Introduction

A number of interesting models predict particles which can be produced in association with W bosons and which decay to heavy quarks. In some technicolor models the process $p\bar{p} \to \rho_T \to W\pi_T$ with $\pi_T \to b\bar{b}$ can have a cross section as high as 10 pb.[1] Higgs bosons may be produced by $p\bar{p} \to W^* \to WH$, although the cross section for this process, about 0.3 pb for $m_H = 100$ GeV/c^2, is expected to be below sensitivity until the next Tevatron collider run if the Standard Model is correct.[2] The present search is motivated by the observation that such a signature is a plausible feature of new physics and is one which the DØ detector is well suited to observe.

5 Event Counting

In the 1992-1995 Tevatron run the DØ experiment recorded about 100 pb^{-1} of data. From this sample we select events containing a W boson by looking for an isolated high p_T lepton, e or μ, and missing transverse energy. Further, we require that there be at least two jets in each event and that one or more of the jets be tagged as a b-quark jet by the presence of a muon within the jet cone. The final sample contains 27 candidate events, including 12 (15) in which the isolated lepton is an electron (muon).

The largest source of background is W bosons with jets produced by radiation. These jets are not enriched in heavy flavor and are expected to have approximately the same muon content as those in ordinary multijet events. The fraction of jets which contain a tagging muon is measured in multijet data and parameterized as a function of jet p_T and η. Of the 1940 inclusive $W+ \geq 2$ jet events we expect 13.9 ± 2.1 to have a tagging muon. The reliability of this procedure has been tested by using the parametrization to predict the number of tagged jets in a variety of data samples and found to be accurate to 15%.

The second largest background is $t\bar{t}$ pairs. These events contain both W bosons and a pair of b-quark jets. We expect 7.2 ± 2.5 of the candidates to be from this source based on the measured value of the $t\bar{t}$ cross section and a Monte Carlo calculation of the acceptance. [3]

Multijet events which do not contain a real lepton from W or Z decay can enter the sample if a jet mimics an electron shower or contains a muon and deposits little energy in the calorimeter. The number of such events in the sample of candidates is estimated by relaxing the lepton identification criteria. This yields a sample with slightly more events containing true leptons from W decay and many more events containing false leptons. We have studied the effect of loosening these requirements on the acceptance for both true and false leptons and from this infer the expected number of true and false leptons in the sample to be 4.2 ± 0.6.

Z + jets events can mimic the signal if $Z \rightarrow \mu\mu$ and one of the muons overlaps with a jet. Events in which the isolated lepton is a muon are tested for consistency with $Z \rightarrow \mu\mu$. The ones that agree well are removed. The remaining Z background is estimated using Monte Carlo to be 0.2 ± 0.1.

The combined background estimate is 25.5 ± 3.3, consistent with the observed 27 candidates.

In order to express the results as cross section limits we choose WH as a signal model and calculate acceptances using Monte Carlo. Final acceptances, including the branching fraction to e or μ, vary from 0.0052 ± 0.0004 to 0.0092 ± 0.0006 for masses between 80 and 120 GeV/c^2. Fig. 6 shows the central value and 95% C.L. upper limit on the cross section as a function of mass for this model. These results assume that X does not have a significant brancing fraction to light quarks compared to $b\bar{b}$.

6 Dijet Mass Spectrum

Signal events should exhibit a peak in the dijet mass spectrum. The dijet mass distribution of the 27 candidate events is shown in Fig. 7. Also shown is the expected distribution from background events. The line shape for signal events is calculated by Monte Carlo. For a given signal mass, we make a binned maximum likelihood fit for the fraction of signal events in the data. The likelihood function is $L = \prod_{i=1}^{Nbins} e^{-\mu_i}\mu_i^{N_i}/N_i!$ where N_i is the number of data events in the ith bin, $\mu_i = N[f_i^B(1-\alpha) + f_i^S\alpha]$, N is the total number of candidates, f_i^B (f_i^S) is the fraction of background (signal) in the ith bin, and α is the fraction of candidates which are signal events. For each mass value considered the fit is consistent with zero signal events in the data. Upper limits on the cross section are set. The results are shown in Fig. 6.

7 Conclusion

DØ has made a preliminary search for particles produced in association with W bosons which decay to b-quark pairs. We find 27 candidate events with an expected background of 25.5 ± 3.3. The dijet mass spectrum of the candidates is consistent with background. Upper limits on the cross section for the signal model are a few tens of picobarns for signal masses near 100 GeV/c^2.

We acknowledge the support of the US Department of Energy and the collaborating institutions and their funding agencies in this work.

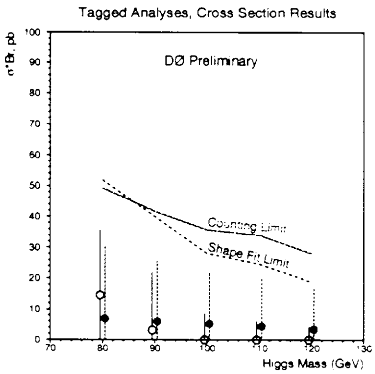

Figure 6: Central values and 95% C.L. upper limits for the signal model cross sections.

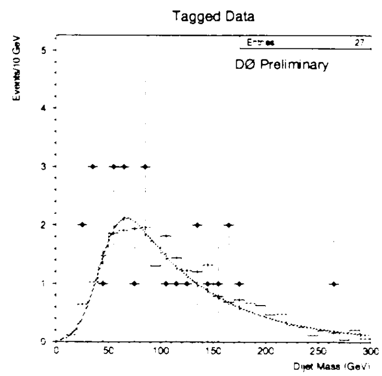

Figure 7: The dijet invariant mass distribution for data (points) and background (histogram). The smooth curve is a parametrization of the background shape.

References

1. E. Eichten and K. Lane, FERMILAB-PUB-96/075-Y, BUHEP-96-9, hep-ph/9607213.
2. "Report of the Tev_2000 Study Group on Future Electroweak Physics at the Tevatron", D. Amidei and R. Brock, ed.s, FERMILAB-PUB-96/082.
3. R. Kehoe (for the DØ Collaboration), "Measurement of the Top Quark Cross Section at DØ ," these proceedings.

SEARCH FOR FIRST GENERATION SCALAR LEPTOQUARKS AT DØ

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We have searched for the pair production of first generation scalar leptoquarks decaying into electron + quark with branching ratio β with the DØ detector at the Fermilab $p\bar{p}$ collider with $\sqrt{s}$ = 1.8 TeV. Using 93.7 pb^{-1} of data, two candidate events were found and were consistent with Standard Model backgrounds. Using a Monte Carlo prediction for $\sigma(p\bar{p} \rightarrow S_1\bar{S}_1 + X)$, we exclude $M_S < 194(143)$GeV/c^2 for $\beta = 100(50)\%$.

8 Introduction

Leptoquarks (LQ) are exotic particles which are present in many theories beyond the standard model (SM).[1,2] The DØ collaboration has published[3] the result of a search for pair-produced first generation scalar leptoquarks from $2e$ + 2jets and $1e$ + $\not{E}_T$ + 2 jets channels, using 13.4 pb^{-1} of data obtained in Run Ia. In this paper, we report the result from the $2e$ + 2 jets channel using a larger data set (93.7 pb^{-1}) from Run Ib.

9 Analysis

9.1 Monte Carlo (MC) Expectations

ISAJET Monte Carlo[4] with MT–LO structure functions[5] was used to estimate the pair production cross section and to study the detailed properties of the signal for M_S between 40 and 250 GeV. All MC events were passed through the DØ detector simulation and subjected to the same event reconstruction algorithms as the DØ collider data. From the MC studies, the electrons and final-state jets from the massive leptoquark decay are expected to be predominantly in the central region and well separated from each other. Background to this two electron channel is mainly due to production of Z, γ^* + 2 jets, $t\bar{t}$, and misidentified multi-jet events. Based on MC study of signal and background, the following cuts were applied to select leptoquark candidate events: (i) two good electrons with $E_T > 25$ GeV and $|\eta| < 2.5$, with at least one of the electrons in the Central Calorimeter (CC) region, i.e. within $|\eta| < 1.2$. (A "good electron" is an EM cluster passing one set of electron quality cuts[6]: EM fraction EMF > 0.9, H-matrix $\chi^2 < 100$, cluster isolation ISO < 0.15, track match

Table 1: Total efficiency (ε), combined systematic and statistical uncertainties ($\delta\varepsilon/\varepsilon$), predicted $S_1\bar{S}_1$ production cross section (σ_{MC}), total number of expected events (N_{TOT}) in DØ for $\beta = 100\%$.

M_S (GeV)	Eff. $\varepsilon(\%)$	$\delta\varepsilon/\varepsilon(\%)$	σ_{MC} (pb)	N_{TOT}	$\sigma_{95\%CL}$
40	0.27	52	820	207	65.8
60	2.28	27	109	233	3.1
100	11.32	15	7.40	78	0.48
150	20.50	11	0.84	16	0.26
200	28.82	9.7	0.157	4.2	0.183
250	31.21	9.2	0.036	1.1	0.168

significance $\sigma_{trk} < 10.0$, $\frac{dE}{dx} < 1.5$ or > 3.0 for CC and $\frac{dE}{dx} < 1.3$ or > 2.5 for EC region). (ii) two jets with $E_T > 30$ GeV $|\eta| < 2.5$, with both jets separated from the electron in $\eta \times \varphi$ space: $\delta R(e,j) = \sqrt{(\Delta\eta)^2 + (\Delta\varphi)^2} > 0.25$. Furthermore, jets are required to have $\varphi(j) > 1.8$ or < 1.65 in order to avoid the jet energy mismeasurement due to the Main Ring. (iii) remove electron pairs with $75 < M_{ee} < 106$ GeV$/c^2$. This cut rejects 83% of the Z,γ^* background while it retains 75(90)% of the MC signal for $M_S = 40(250)$ GeV$/c^2$. The cross section, signal efficiency and the total number of expected events after all cuts (assuming $\beta = 100\%$) are presented in Table 1. The uncertainties arise from the statistical and the jet-energy scale uncertainties.

9.2 DØ data

The data used for this analysis were taken with the DØ detector [7] during Run Ib from November 1993 to August 1995. The data sample representing a total integrated luminosity of $L = 93.7\text{pb}^{-1}$ was obtained using a trigger with two electromagnetic (EM) cluster requirements. The hardware portion of this trigger required at least 2 EM towers (0.2×0.2 radians in $\eta \times \phi$ space) with transverse energy $E_T > 7$ GeV and the software portion required one or more EM clusters with $E_T > 20$ GeV with electron shape and isolation requirement, and two or more EM clusters with $E_T > 16$ GeV, with electron shape and isolation requirements. Two events survived all the selection cuts. The expected number of background events was estimated to be about 3.49 ± 1.10 events from Drell-Yan, $t\bar{t} \to \ell\ell$, $Z \to \tau\tau \to \ell\ell$, $WW \to ee$ and QCD background. Therefore, there is no evidence for $S_1\bar{S}_1$ production. From this null result, using Bayesian statistics [8], and taking into account the statistical error, jet-energy scale uncertainties and the integrated luminosity uncertainty,

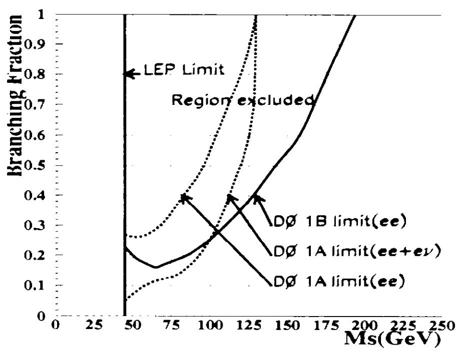

Figure 8: The DØ preliminary 95% CL excluded region of branching fraction vs M_S.

a preliminary upper limit 95% CL on the cross section was determined which is shown in Table 1.

10 Conclusion

Comparing the measured upper limit on the cross section with the theoretical cross section from ISAJET with MT leading order parton distribution functions, the DØ preliminary 95% CL excluded region of branching ratio vs M_S is given in Figure 8. The mass limits for first generation leptoquarks are 194(143) GeV/c^2 for branching ratio $\beta = 100(50)\%$.

References

1. J. Pati and A. Salam, *Phys. Rev.* D **10**, 275 (1974).
2. W. Buchmüller and D. Wyler, *Phys. Lett.* B **177**, 377 (1986).
3. DØ collaboration, S.Abachi *et al.* *Phys. Rev. Lett.* **72**, 965 (1994).
4. F.Paige and S.D.Protopopescu, Brookhaven National Laboratory Report No. BNL 38034, 1986 (unpublished).
5. J.G. Morfin and W. K. Tung, *Z. Phys.* C **52**, 13 (1991).
6. DØ collaboration, S.Abachi *et al.* *Phys. Rev.* D **52**, 4877 (1995).
7. DØ collaboration, S.Abachi *et al.* *Nucl. Instrum. Methods* A **338**, 185 (1994).
8. I.Bertram *et al.* DO Note 2775A, unpublished.

Search for SUSY Gaugino Production Through the Trilepton Signature

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We will present preliminary results on the search for SUSY gauginos through the trilepton signature with the DØ detector. These results are based on 90 pb^{-1} of data taken during the 1994-1995 Tevatron collider run. These new data significantly extends the search reach of 12 pb^{-1} from the 1992-1993 run.

11 Introduction

The trilepton signal is a distinguishing signature for SUSY [1]; it has few Standard Model (SM) backgrounds. SUSY is currently the most favored extension of the SM needed to overcome problems such as the Higgs mass scale (fine tuning) problem and unification of the gauge couplings at large mass scales. In the Minimum Supersymmetric Standard Model (MSSM), every SM particle has a SUSY partner which differs from its SM partner by 1/2 integral spin and by its mass. We assume that the lightest SUSY particle (LSP) is stable.

This analysis deals with the search for the production of neutralino ($\tilde{Z}_i$) – chargino ($\tilde{W}_i$) pairs which can decay (eg. $\tilde{Z}_2 \rightarrow Z^* + \tilde{Z}_1(\mathrm{LSP}) \rightarrow e^+e^- + \tilde{Z}_1$) and produce the trilepton signature. The leptons are isolated, and the events are hadronically quiet. Only electrons and muons (not from τ decay) are considered here; therefore, we have four channels to search in: $eee, ee\mu, e\mu\mu$, and $\mu\mu\mu$. The major backgrounds are instrumental and arise from SM processes (Z, $b\bar{b}$) with additional fake electrons and isolated muons from b or c quarks. The physics background is SM WZ boson pair production which is much smaller at least by an order of magnitude.

12 Analysis

To describe the analysis, we will begin by giving the trigger conditions and then work our way through the offline selection. A description of the DØ detector can be found elsewhere [2]. Five triggers were used in this analysis: a single electron trigger requiring one electron with $p_T >$ 20 GeV/c and missing E_T ($\not{E}_T$) > 15 GeV; a dielectron trigger requiring one electron with $p_T >$ 12 GeV/c, a second electron with $p_T >$ 7 GeV/c, and $\not{E}_T$ > 7 GeV; an electron – muon trigger with one electron with $p_T >$ 7 GeV/c and one muon with $p_T >$ 8 GeV/c; a single muon trigger requiring one muon with $p_T >$ 15 GeV/c; and a dimuon trigger requiring two muons with $p_T > 3$ GeV/c. The analysis for each of the channels requires three isolated leptons with $p_T > 5$ GeV/c. In addition we require that one or two leptons be consistent with the trigger threshold plus 2 GeV/c. We require muons to be within a pseudo-rapidity of 1.0.

For the three electron channel in addition to the above cuts we require that the invariant mass of the two leading electrons not be within the range 81 to 101 GeV/c^2. We also require that the two leading electrons not be back to back within 0.1 radians in ϕ. The $\not{E}_T$ is required to be greater than 15 GeV.

For the two electron plus one muon channel the $\not{E}_T$ and leading muon are required not to be back to back in ϕ within 0.1 radians or be pointing parallel within 0.1 radians of each other. This angle cut reduces instrumental backgrounds due to the gross mismeasurement of the muon p_T. These muon-$\not{E}_T$ angle cuts are also applied in a similar manner to the two muon plus one electron channel where we also require the two leading muons not to be back to back in ϕ within 0.1 radians. This cut reduces greatly the background from cosmics and the Z boson background. The two leading muons must not be pointing in the same direction in ϕ within 0.2 radians, which eliminates the J/Ψ background.

Finally, for the three muon channel we require that the three leading muons not be back to back in ϕ within 0.1 radians. The invariant mass of all three combinations must be greater than 5 GeV. We apply similar angle cuts on the $\delta\phi$ between the muon and $\not{E}_T$ as before. We also require $\not{E}_T > 10$ GeV.

We see no events in any of the channels. We expect backgrounds of 0.36 ± 0.07, 0.68 ± 0.38, 0.16 ± 0.04, and 0.2 ± 0.04 events for the $eee, ee\mu, e\mu\mu$, and $\mu\mu\mu$ channels respectively for a total of 1.4 ± 0.39 events.

The efficiency for the trilepton signal was determined with **ISAJET V7.13** [3] Monte Carlo processed with a full simulation of the DØ detector. The MSSM option in **ISAJET** was used to generate samples with chargino masses between 45 and 96 GeV/c^2 where the efficiencies varied between 1.6% and 9.7% for the eee channel, 1.1% and 5.5% for the $ee\mu$ channel, 0.9% and 2.9% for the $e\mu\mu$ channel, and 0.5% and 1.4% for the $\mu\mu\mu$ channel. The signal efficiency is dependent on choice of SUSY parameters via the relation between the mass of the three lightest gauginos. In our case $M_{\tilde{Z}_2} \simeq M_{\tilde{W}_1} \simeq 2\times M_{\tilde{Z}_1}$. This relation holds true for a large portion of parameter space. However, as the mass of the LSP ($\tilde{Z}_1$) becomes relatively heavier, the kinematic efficiencies diminish.

13 Results and Conclusion

With no evidence of a trilepton signal, we calculate the 95% CL limit on the cross section times branching fraction to any given channel. This limit is given

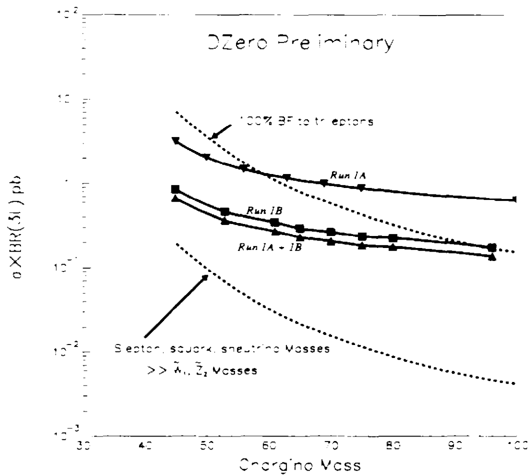

Figure 9: The preliminary 95% CL upper limit on the cross section time branching fraction of a single channel.

in figure 9. The 1992-1993 run (1A) limit[4], the 1994-1995 run (1B) limit, and the combined limit are given. These limits are appropriate for those SUSY models whose parameters are chosen such that the mass relation $M_{\tilde{Z}_2} \simeq M_{\tilde{W}_1} \simeq 2\times M_{\tilde{Z}_1}$ is satisfied. The upper dashed theory curve corresponds to maximal branching to leptons which can occur if the mass of the charged sleptons are lighter than the mass of the $M_{\tilde{Z}_2}$ and $M_{\tilde{W}_1}$. The lower theory curve represents the case where sleptons are heavy and the gauginos decay via off-shell W and Z bosons which have SM branchings to leptons.

References

1. Mod. Phys. Lett. **A2**, 331 (1987). Phys. Rev. **D47**, 2739 (1993). Phys. Rev. **D52**, 1565 (1995).
2. Nucl. Instr. Meth. **A 338**, 185 (1994).
3. ***Supercollider Physics***, p. 41, ed. D. Soper (World Scientific, 1986). ***Proceedings of the Workshop on Physics at the Current Accelerators and Supercolliders***, p. 703, ed. J. Hewett ***et al.*** (Argonne National Laboratory, 1993).
4. Phys. Rev. Lett. **76**, 2228 (1996).

SEARCH FOR HEAVY NEUTRAL GAUGE BOSONS AT DØ

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We report preliminary results on a search for a heavy neutral gauge boson, Z', using the decay channel $Z' \to ee$. The data were collected with the DØ detector at the Fermilab Tevatron during the 1994–1995 $\bar{p}p$ collider run at $\sqrt{s} = 1.8$ TeV and correspond to an integrated luminosity of ≈ 90 pb^{-1}. Limits are set on the cross section times branching ratio for the process $\bar{p}p \to Z' \to ee$ as a function of the Z' mass. We exclude the existence of a heavy neutral gauge boson of mass less than 660 GeV/c^2 (95% CL), assuming a Z' with the same coupling strengths to quarks and leptons as the standard model Z boson. Combining this analysis with DØ 's 1992–1993 data set, increases the limit to $m_{Z'} > 670$GeV/c^2 .

14 Introduction

The standard model is the generally accepted theory describing elementary particles and their interactions. Despite its success, it is not considered to be the ultimate theory. Numerous extensions to the standard model have been proposed [1], many of which include additional neutral gauge bosons, believed to be heavier than the standard model Z. In this analysis we consider a reference model Z' with the same coupling strengths to quarks and leptons as the standard model Z and with decay to W and Z bosons suppressed. The width of the Z' is taken as the Z width, scaled with the mass, allowing appropriate decays to top.

Using ≈ 90 pb^{-1} of data collected by the DØ detector [2] at the Fermilab $\bar{p}p$ collider with a center of mass energy of 1.8 TeV, we search for the Breit-Wigner peak of a Z' superimposed on the invariant mass spectrum expected in the standard model from Z production and Drell-Yan continuum decaying to electron-positron pairs. We set a limit on the cross section times branching ratio for the process $\bar{p}p \to Z' \to ee$ and use this limit to set a lower bound on the mass of our reference model Z'.

15 Event Selection

At DØ , electrons are detected in hermetic, uranium liquid-argon calorimeters [3,4], with an energy resolution of about $15\%/\sqrt{E(\mathrm{GeV})}$. The calorimeters have a granularity of $\Delta\eta \times \Delta\phi = 0.1 \times 0.1$, where η is the pseudorapidity and ϕ is the azimuthal angle.

The trigger requires two isolated EM clusters with transverse energy $E_T >$ 20 GeV. The offline electron identification requirements are applied to both EM candidates and consist of the following: *i*) the electron has to deposit at least 95% of its energy in the 21 radiation length electromagnetic calorimeter, *ii*) the transverse and longitudinal shower shapes have to be consistent with those expected for an electron (based on test beam measurements), and *iii*) the electron has to be isolated [5]. In addition, at least one of the electrons has to have a good match between a reconstructed track in the drift chamber system and the shower position in the calorimeter.

The fiducial region for electrons accepted in this analysis is $|\eta| < 1.1$ (central) or $1.5 < |\eta| < 2.5$ (forward). For electrons in the central region, energy clusters within 0.01 radians in ϕ of module boundaries located every 0.2 radians in ϕ are excluded. At least one of the electrons has to be central. The kinematic selection requires one electron with $E_T > 30$ GeV and the second electron with $E_T > 25$ GeV.

The dielectron invariant mass spectrum for the 5707 events that pass this selection is shown in figure 1.

16 Backgrounds

The QCD multijet background remaining in the sample is determined from data. To select the background sample, we keep events with two electromagnetic jets that pass the fiducial and kinematic cuts, but fail the electron identification. We then fit the invariant mass distribution of the candidate sample to a linear sum of a Monte Carlo simulated Z line shape plus the multijet background. We estimate the amount of background in the candidate sample to be $\approx 3\%$. For $m_{ee} > 300$ GeV/c^2 we expect 5.8 events from Z continuum and Drell-Yan production and observe six events. Above 500 GeV/c^2 we expect 0.3 events and observe one.

17 Results

A limit is obtained for our reference model Z' production by studying the ratio $\sigma(\overline{p}p \rightarrow Z' + X)BR(Z' \rightarrow e^+e^-)/\sigma(\overline{p}p \rightarrow Z + X)BR(Z \rightarrow e^+e^-)$. The relative acceptance for Z' to Z production is determined from Monte Carlo simulation [6]; a conservative uncertainty of 10% due to the choice of PDF's is assigned at this stage of the analysis. The integrated luminosity and event selection efficiency for Z' and Z are taken to be the same.The production limit is obtained for a range of Z' masses by constructing probability distributions for Z' production based on the events observed in a mass window given by

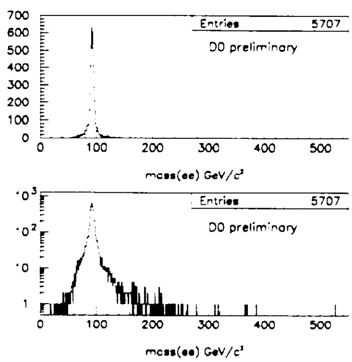

Figure 10: The dielectron invariant mass spectrum from 90 pb^{-1}.

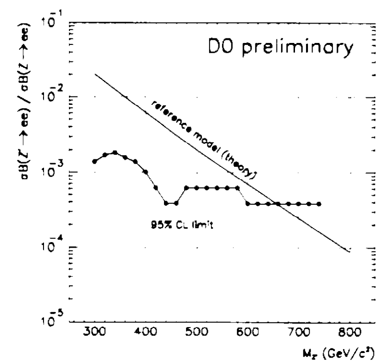

Figure 11: DØ 's 95% CL upper limit as a function of $m_{Z'}$ compared to the theoretical prediction from reference 7.

$m_Z 0 \pm 4\Gamma_Z 0$ The region above the limit curve in figure 2 is excluded. From the intersection of the limit and theory [7] curves, we exclude the existence of a Z' from the process $\bar{p}p \rightarrow Z' \rightarrow ee$ for $m_{Z'} < 660$ GeV/c^2 , at 95% CL. Combining this analysis with $\approx$ 15 pb^{-1} of data taken by DØ during 1992–1993, increases the limit to $m_{Z'} > 670$GeV/c^2 .

18 Conclusions

Based on a preliminary analysis of $\approx$ 105 pb^{-1} of data taken by the DØ $\bar{p}p$ collider detector, we exclude the existence of a heavy neutral gauge boson of mass less than 670 GeV/c^2 (95% CL), assuming a Z' with the same coupling strengths to quarks and leptons as the standard model Z boson.

1. R. Mohapatra, ***Unification and Supersymmetry***, Springer-Verlag (1992).
2. S. Abachi ***et al.***, Nucl. Instr. and Methods **A 338** 185 (1994).
3. H. Aihara ***et al.***, Nucl. Instr. Meth. **A325**, 393 (1993).
4. S. Abachi ***et al.***, Nucl. Instr. Meth. **A324**, 53 (1993).
5. S. Abachi ***et al.***, Phys. Rev. Lett. **75**, 1456 (1995).
6. PYTHIA Monte Carlo with MRSD−′ pdf's. T. Sjöstrand, ***Computer Physics Commun.*** **82**, 74 (1994); A.D. Martin, R.G. Roberts and W.J. Stirling, ***Phys. Lett.*** B **306**, 145 (1993).
7. Hamberg, van Neerven and Matsuura, Nucl. Phys. B **359**, 343 (1991).